Abstract for a paper to be presented at the 30th International Conference on Environmental Systems, Toulouse, France, July 10-13, 2000

Thermal Control of Mars Lander and Rover Batteries and Electronics Using Loop Heat Pipe and Phase Change Material Thermal Storage Technologies

Gajanana C. Birur*, Kenneth R. Johnson, Keith S. Novak, and Tricia W. Sur
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

* 4800 Oak Grove Drive, MS 125-109, Pasadena, California, USA
Phone: 818/354-4762, Fax: 818/393-1633; Gaj.birur@jpl.nasa.gov

ABSTRACT

A harsh thermal environment, marked by wide diurnal swings in atmospheric temperatures, is one of the key challenges to the long-term survival of Mars landers and rovers. The ambient atmospheric temperatures on Mars range from +10 °C during the day, to as low as –90 °C at night. Various passive thermal control techniques have been used in past Mars missions to keep the temperatures of the electronics, science equipment, and batteries in landers and rovers within their acceptable limits. Of all the equipment used on these Mars vehicles, batteries are the most temperature sensitive. Batteries can age prematurely at elevated temperatures (above 40 °C) and electrolytes can freeze at low temperature (below –30 °C). The Mars Pathfinder lander stopped functioning on the surface of Mars due in part to the degraded performance of its batteries caused by low temperature operations..

The present paper describes a novel thermal control system for future Mars landers and rovers to keep their battery temperatures within the –10 °C to +25 °C temperature range. To keep the battery temperatures above the lower limit, the system uses a phase change material (PCM) thermal storage module to store heat and a loop heat pipe (LHP) to transfer heat between a set of Radioisotope Heater Units (RHUs) and the battery. To keep the battery temperature below the upper limit, a thermal control valve in the LHP opens to redirect the working fluid to an external radiator where excess heat is dumped to the atmosphere.

The PCM thermal storage module was designed and fabricated using dodecane paraffin wax (melting point, –10.5 °C) as the phase change material. It stores thermal energy when the battery is above –10 C and releases that energy to maintain the battery above –10 °C as the liquid wax solidifies during the cold Martian night. This design also incorporates a lightweight aluminum jacket and carbon fibers interspersed within the PCM to provide thermal and structural reinforcement to the module. The module provides a thermal energy storage of 30 Watt-hours and weighs 820 grams. The module has demonstrated a reliable thermal performance through seven thermal cycles with temperature ranging from –60 to +10 °C. A miniature ammonia loop heat pipe with two condensers and an integrated thermal control valve was designed and fabricated for use with the PCM thermal storage unit. The first condenser is integrated with the thermal storage unit, and the second condenser is a 10" X 12" external aluminum radiator. The thermal control valve bypasses the second condenser whenever the battery temperature is below 25 °C. The LHP and the radiator weigh less than 700 grams.

Adv-tch\\papers\ices-2000\abs-ICES00-1.doc
9/15/199909/24/99; G. Birur

The present paper also describes results from an experimental simulation of the Mars '03/'05 rover thermal performance in the Martian environment. An aluminum box with batt insulation simulated the rover internal thermal environment. A heat exchanger located at the bottom of the box controlled the box temperature to the Mars diurnal temperature variation on the rover internal walls. The Mars rover battery and RHUs were simulated using thermally equivalent aluminum blocks and were installed inside the rover box along with the LHP and PCM to simulate the rover thermal design. The radiator was mounted outside the rover box and its temperature was controlled by a nitrogen heat exchanger. The diurnal temperature variation of the rover inside walls and the external radiator was calculated using a thermal model of the rover in the Martian environment. Tests are currently being performed for various internal configurations of the PCM and LHP arrangements including worst case hot and cold cases. Based on the results of these tests, the Mars '03/'05 rover thermal design development will be finalized.

Many lessons are being learned during the development and implementation of these thermal technologies for Mars rover battery thermal control. Recommendations for the design and operation of loop heat pipe and phase change material thermal energy storage systems for future space missions will be made in the paper.

References:

1. G. Birur, J. Rodriguez, and M. Nikitkin, "Loop Heat Pipe Applications for Thermal Control of Mars Landers/Rovers," presented at the Tenth Annual Spacecraft Thermal Control Technology Workshop, the Aerospace Corporation, El Segundo, California, February 24-26, 1999.